ORIGINAL RESEARCH

Evaluation of Reliability and Validity of Occlusal Caries Detection by Direct Visual, Indirect Visual and Fluorescence Camera Using ICDAS II (Codes 0, 1, and 2): An *In Vivo* Study

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Abstract

Introduction: Early detection of carious lesions paves the way for the preservation of tooth structures by remineralization strategies. Visual examination using international caries detection and assessment system (ICDAS) II has been validated with the gold standard of histological classification. A fluorescence camera is yet another diagnostic aid for the early detection of carious lesions based on the autofluorescence of the enamel and dentin. This study was done to evaluate the validity of the fluorescence camera (Soprocare and Acteone) in detecting early carious lesions.

Materials and methods: A total of 690 occlusal surfaces of non-cavitated premolars and molars were examined by examiners 1 and 2, trained in the ICDAS II grading system. The photographs of the occlusal surface and the fluorescence images, which were taken using a Soprocare (Acetone) intraoral camera, were examined by examiners 3 and 4. The scoring was tabulated and correlated.

Results: The κ values for interexaminer reproducibility of indirect visual was 0.841 (good), and his fluorescence camera was 1.00, which is very good. The correlation analysis revealed that there was a higher correlation between direct visual and indirect visual for both examiners when compared to direct and fluorescence cameras. There was a positive relationship between indirect visual and fluorescence cameras for both the experimenter). The indirect visual method for the detection of carries has high sensitivity and specificity irrespective of the examiner. Examination by fluorescence camera has a low sensitivity and high specificity.

Conclusion: The specificity of the caries detection method by indirect visual examination based on ICDAS II coding that of the Soprocare fluorescence camera was consistent and reliable, whereas indirect visual examination had a high sensitivity for detecting ICDAS codes 1 and 2. Soprocare showed a very low sensitivity in detecting ICDAS code 1 and 2 lesions.

Keywords: Dental caries, Direct visual examination, Fluorescence camera, International caries detection and assessment system II, Incipient lesions detection.

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Introduction

Dental caries is a complex as well as dynamic process which is influenced by a multitude of factors that initiate the progression of the disease. It is among one the most prevalent chronic disease that affects mankind.[1]

Any surface of the tooth is prone to dental caries. The occlusal surface is, however, the most common and vulnerable area for dental caries initiation due to the intricate anatomy of the occlusal groove and fossa system.[2] The frequent accumulation of plaque and the presence of stains makes it difficult to detect dental caries on the occlusal surface.[3,4] The early detection of caries acts as the precursor in obtaining the outcome of the procedure to be done for a proper appropriate treatment to be done beforehand; detecting carious lesions precisely is often challenging. Early detection of dental caries requires proper guidelines and clinical examination tools. The ICDAS II system, which is proposed for visual examination, has been designed in such a way that it explains the tooth status and the caries status.[5,6] The ICDAS II system enables early detection of caries as it correlates with histological examination.[7–9] Thereby, preventive and minimally invasive management steps can be implemented successfully.

On the other hand, clinical examination tools used for occlusal caries detection traditionally used to be mouth mirrors, optimal light, and dental probes. A sharp probe can cause irreversible traumatic defects in early demineralized areas. It also causes damage to specific remineralized subsurface lesions, and there are theoretical concerns regarding bacterial cross-infection. This can be prevented by using a ball-ended probe which is recommended by the ICDAS

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system.[10] Other modalities like laser and light fluorescence-based methods could be employed in caries detection; intraoral cameras, magnification loupes, and operating microscopes are used for caries detection.[6] These aids will improve on detection of early caries.

Detection of caries using an advanced method like a fluorescence camera allows both clinician and patient to visualize the condition of the teeth. Some artificial and natural materials absorb energy at certain wavelengths and emit light at longer wavelengths. This property is called fluorescence.[11] Although it is not visible in daylight, normal fluorescence of teeth contributes significantly to its emergence. A fluorescence camera has the ability to distinguish sound and carious tissue by an excitation source that emits a light that is partially absorbed by the dental substance. The absorbed light is then reemitted by chromophores within the dental tissue at a longer wavelength.[12] Enamel has a smaller fluorescence index compared to dentine because dentin has a greater amount of organic materials.[13] This principle is used in quantitative light-induced fluorescence in which they reconstructed the fluorescence image using an algorithm. This enables the detection of early dental caries. Soprocare (Acteone) is a fluorescence camera which uses an artificial light source with a specific wavelength (440nm), to illuminate dental tissue. It works on the principle of autofluorescence, which is due to the existence of endogenous fluorophores found in the enamel and dentine. According to the manufacturer, The strong red color in the CARIO (Its the mode in fluorescence camera in which the camera uses the visible blue light frequency with wavelength 450 nm to illuminate the surface of the teeth.) setting clearly reveals enamo-dentinal caries.[11]

Literature search on ICDAS II as the criterion for scoring where occlusal caries are found shows that the evaluation of caries by direct visual examination showed high sensitivity and moderate specificity in the initial stage of caries progression.[11,14] Thus, the detection of incipient caries becomes challenging. Based on this lacunae, In this study, ICDAS II visual examination criteria is carried out by indirect visual method and with a fluorescence camera, with the research question "Is the diagnosis of occlusal surface caries by indirect visual and fluorescence camera compared with visual examination with ICDAS II (codes 0, 1, and 2) will have same reliability and validity?"

Materials and Methods

Patients from daily Outpatient Department (OPD) of the Department of Conservative Dentistry and Endodontics, Indira Gandhi Institute of Dental Sciences, Puducherry, India, participated in the study. The study was approved by Institutional Review Board (Ref no: IGIDSIRB2015 NDP10PGCKCDE) and the Institutional Ethical committee (Ref no: IGIDSIEC2016NDP10PGCKCDE). A total of 690 non-cavitated and unrestored caries. Occlusal surfaces of premolars and molars were examined. The patients' ages were between 18 and 30, and the exclusion criteria were according to ICDAS II (codes 0, 1, and 2). Teeth with the conditions like fractures, restorations, morphological abnormalities, and hypoplasia were not included in the study. Prior to the procedure patient consent form was obtained.

For detecting caries by direct, indirect visual, and fluorescence camera methods, four examiners were trained based on the ICDAS II system and calibrated. Prior to evaluation, the occlusal surfaces were cleaned with a rotating bristle brush and pumice to remove plaque and other debris and to dehydrate any enamel cavities. Examiners 1 and 2 (direct examiners) performed a visual examination of the teeth using the ICDAS II code and diagnostic instruments. Photographs of the entire examined surface were taken using Soprocare intraoral camera (white light mode and CARIO mode) by examiner 1. In CARIO mode, the camera uses the visible blue light frequency (wavelength 450 nm) to illuminate the surface of the teeth. The vivid red color in the CARIO mode clearly indicates enamo-dentinal caries. The surrounding tissue is shown in black and white, which isolates and emphasizes the carious lesion. The daylight mode provides a white light image with a magnification of >50 times that of the tooth surface, and the CARIO mode works on the principle of autofluorescence, which depends on the existence of endogenous fluorophores found in the enamel and dentine.[15] Photographs were coded by examiners 3 and 4 (indirect examiners), who were blinded for detection of caries by indirect visual and fluorescence cameras from photographs. The fluorescence images of the occlusal surface were scored visually using the absence (score 0) and presence (score 1) of red fluorescence photographs, and the white light photographs were coded according to ICDAS II. Statistical analysis was done. Direct visual, indirect visual, and fluorescence camera values were correlated utilizing the correlation coefficient of Spearman. Each detection method's sensitivity and specificity were determined under ROC.

Results

Table 1 displays the acceptance of the indirect visual assessments and fluorescence cameras between the examiners. The visual examination had a κ value of 0.841 and 1.00 for the fluorescence camera, which is very good. There is no disagreement between examiners on the examination of fluorescence images as it shows the presence and absence of caries.

Table 2 displays direct visual, indirect visual, and fluorescence camera Spearman correlation using ICDAS II at a significant *p*-value of <0.001. Indirect visual examiners 3 and 4 with direct visual examination show a positive correlation of 0.949 and 0.902, respectively. Fluorescence camera examiner 3 and 4 with direct visual examiner shows a positive correlation of 0.140. Indirect visual examiners 3 and 4 with fluorescence camera examiners 3 and 4 show a positive correlation of 0.110 and 0.145, respectively. In comparison to the direct and fluorescent cameras by two examiners, a higher correlation between direct visual and indirect visual was observed. Both the experimenter confirmed a positive relationship between indirect visual and fluorescent cameras. However, this correlation was lesser than the direct vs other methods.

Table 3 shows the sensitivity and specificity of the indirect visual and fluorescence camera. The sensitivity and specificity of each examiner's diagnostic techniques were calculated using the receiver operating characteristic (ROC) curve (Fig. 1). Independent of the examiner, high sensitivity and specificity are offered by an indirect visual technique for the detection of caries, whereas fluorescence camera offers a low sensitivity and high specificity.

Table 1: Interexaminer reproducibility (κ) of indirect visual examination and fluorescence camera

Measurement of agreement	*κ value*	*No. of valid cases*
Indirect visual examination Examiners 3 and 4	0.841	690
Fluorescence camera Examiners 3 and 4	1.00	690

Table 2: Spearman's correlation coefficient of ICDAS-II indirect visual and fluorescence camera

Measurement of correlation	*Values*	*No. of valid cases*
Indirect visual examiner 3 and direct visual examiner 1	0.949**	690
Indirect visual examiner 4 and direct visual examiner 1	0.902**	690
Fluorescence camera examiner 3 and direct visual examiner 1	0.140**	690
Fluorescence camera examiner 4 and direct visual examiner 1	0.140**	690
Indirect visual examiner 3 and fluorescence camera examiner 3	0.110**	690
Indirect visual examiner 4 and fluorescence camera examiner 4	0.145**	690

**Significant $p < 0.001$

Table 3: Shows the optimum sensitivity, and specificity of indirect visual and fluorescence camera

	Examiner 1		*Examiner 2*	
ICDAS	*Sensitivity*	*Specificity*	*Sensitivity*	*Specificity*
Indirect visual	97.2	98.7	93.7	98.7
Fluorescence	9.1	98.3	9.1	98.3

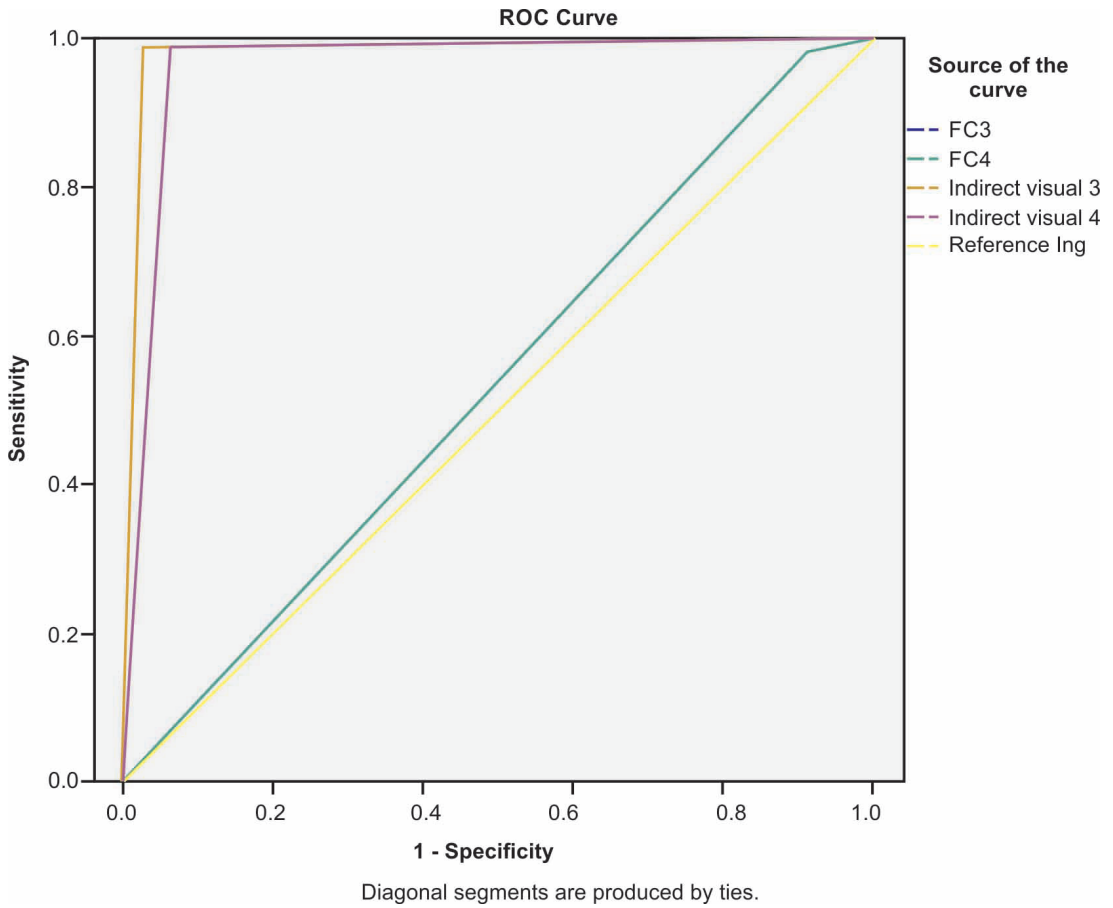

Fig. 1: Shows the optimum sensitivity, and specificity of indirect visual and fluorescence camera of two examiners

Discussion

The non-cavitated lesion seems to be developing slowly, which provides a window of opportunity for applying preventive care to arrest initial lesions. The challenging part is early caries detection.[16]

Clinically caries detection is done by visual inspection, dental mirror, optimal light, a sharp-ended explorer or probe, and radiographs.[3,17] The use of a sharp probe may cause damage to specific remineralizable subsurface lesions, which will lead to the undesirable conversion of non-cavitated lesions to cavitated lesions.[18] Along with traditional caries detection aids, advanced caries detection tools with greater sensitive techniques may enhance caries detection and also assist the clinician in delivering non-operative treatment.[19] But studies have shown that the visual examination is subjective in detecting non-cavitated lesions.[18]

A standard protocol for visual detection of early carious lesions was developed by ICDAS in 2002, which classifies the caries lesion as code 0, 1, 2, 3, 4, 5, and 6 depending on the severity of the lesion in which ICDAS codes 0, 1, and 2 represents non-cavitated caries lesion.[7] In 2008, ICDAS II was proposed as a two-digit coding system in which the first digit shows the tooth status and the second digit shows the carious status was given. ICDAS II system shows the caries site and severity of the lesion compared to the traditional Greene Vardiman Black system, which is only site-specific.[20,21] In the present study, the ICDAS II coding system was used.

International caries detection and assessment system (ICDAS) II codes 1 and 2 represent non-cavitated enamel caries lesions where we can perform preventive measures and non-operative treatment. Based on the ICDAS II system, the International Caries Classification and Management System (ICCMS) has been developed for the implementation of the new model of the caries management system.[22,23] The management elements include preventing new caries, non-operative care of lesions, and tooth-preserving operative care of lesions based on caries risk assessment. The non-operative treatment option for non-cavitated caries using ICCMS criteria includes topical fluoride, oral hygiene with fluoridated dentifrice (1000 ppm), Mechanical removal of biofilm, Resin-based sealants, glass ionomer sealants, resin-based sealants/infiltrates.[23,24] Hence for this study, these codes were used.

All the examiners in this study had undergone training on the ICDAS system through an e-learning program for 90 minutes and offline training under an expert. This helped the examiners to know about the criteria and codes and the examination protocol and to assess the coding system. As an aid to the diagnosis of early caries, devices based on enamel and dentin fluorescence were introduced. Laser fluorescence using red laser light (λ = 655 nm) to illuminate caries lesions in enamel and dentin. The red laser light penetrates porous regions of the tooth and creates an infrared (IR) fluorescence. The normal enamel is transparent to red light. The IR fluorescence is believed to originate from porphyrins and related compounds from oral bacteria. These molecules are chiefly responsible for the absorption of red light.[25,26]

The autofluorescence of enamel and dentin also provides an opportunity to detect early dental caries. Demineralized enamel will fluoresce less, and this loss of fluorescence can be detected, quantified, and longitudinally monitored.[26] The CARIO mode of the Soprocare device detects the autofluorescence using blue light at 450 nm.[27] Purposive random sampling was performed as the study uses the judgment of trained examiners by the ICDAS II system. The occlusal surface of posterior teeth is more prone to caries due to its complex morphology. For this study, a total of 690 occlusal surfaces of non-cavitated premolars and molars of patients from daily OPD were based on ICDAS II. Patients with ages ranging from 18–30 years old were examined for this study. The incidence of the incipient carious lesion is mainly seen in the age-group between 18 and 30 years old. The κ value from the Jablonski-Momeni et al. study was used for the sample size calculation.[6]

Table 4: The reference value of weighted κ

<0.20	Poor
0.20–0.40	Fair
0.40–0.60	Moderate
0.61–0.80	Good
0.81–1.00	Very good

The reference values of weighted κ are illustrated in Table 4. In this study, the κ values between the examiners for indirect visual and fluorescence camera is 0.841 and 1.00, respectively, which were very good. It is in accordance with A. Theocharopoulou et al. study in 2015 and Mona Zeitouny et al. study in 2014.[9,11] This shows the reliability of ICDAS II by indirect and fluorescence caries detection methods among examiners.

Spearman's correlation coefficient is a nonparametric measure of rank correlation (statistical dependence between the ranking of two variables). The study compared both indirect visual and fluorescence cameras with direct visual. There was a higher correlation of 0.949 and 0.902 between direct visual and indirect visual examination with correlation analysis by examiners 3 and 4. The correlation analysis revealed a very weak correlation of 0.140 between direct visual and fluorescence examiners 3 and 4. It also produces a not significant value as the correlation between all the methods and examiners was reliable.

The sensitivity and specificity of the indirect visual and fluorescence camera were calculated under the ROC curve. The sensitivity and specificity of indirect visual and fluorescence cameras, irrespective of examiners, were 97.2–98.7 and 9.1–98.3. High sensitivity and specificity were displayed by the indirect visual assessment technique, whereas low sensitivity and high specificity were provided by the fluorescence camera. The Soprocare fluorescence camera examination has a high specificity but a low sensitivity which may result in missing the detection of the non-cavitated carious lesion. This result may be due to the very low depth of non-cavitated caries, absence of porphyrins, interference of the light, and prophylactic paste, which might reduce sensitivity.[9] However, the actual Soprocare device does not include any software algorithm that may enhance its capability to detect early caries. The software algorithm, as described by Zeitouny et al., may enhance the sensitivity of the device in detecting ICDAS II codes 1 and 2.

Conclusion

Caries detection method by indirect visual examination using Soprocare fluorescence camera based on ICDAS II coding exhibited a consistent and reliable level of specificity and low level of sensitivity, but indirect visual examination had a high sensitivity for detecting ICDAS codes 1 and 2.

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